FOREST PEST MANAGEMENT
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AN EVALUATION OF CONIFER MORTALITY ON THE SAN BERNARDINO NATIONAL FOREST BETWEEN MAY 1981 AND MAY 1982

Report No. 83-35

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ABSTRACT

The amount, characteristics, and causes of forest-wide mortality on the commercial forest land of the San Bernardino National Forest were estimated for the period May 1981 to May 1982. Precipitation during the water year (July-June) of 1980-1981 was below normal and it was expected that tree mortality would increase over that which was estimated to have occurred during the years 1976-1978. The estimated total number of dead trees was approximately 16,000 with a volume of over 8 million board feet. This compares with almost 7,000 trees and 3 million board feet annual mortality in 1976-1978. Two-thirds of the number of trees and one-half of the volume was white fir mortality. Jeffrey pine constituted over one-fourth of the trees and over one-third of the volume. Coulter pine, sugar pine, and singleleaf pinyon pine made up the remainder. On average, there were 0.13 trees with 68 board feet killed per acre. Beetles, acting alone, accounted for 33% of the number of dead trees while the interaction of beetles and pathogens was responsible for 59%. Three organisms accounted for over 90% of the number and volume of white fir mortality: fir engraver, fir true mistletoe, and Fomes annosus. Over three-fourths of the number and volume of dead Jeffrey pines involved at least one of the following three organisms: Jeffrey pine beetle, California flatheaded borer, and F. annosus. At least ninety-five percent of the number and volume of dead Coulter pines was attributed to at least one of the following three organisms: western pine beetle, western dwarf mistletoe, and red turpentine beetle. Ninety percent of all dead trees showed evidence of beetle attack.

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INTRODUCTION

Forest Pest Management, in cooperation with the San Bernardino National Forest and the University of California, conducted an evaluation of conifer mortality on the Forest during the years 1976, 1977, and 1978. The results of the evaluation were previously provided to the Forest (see 3430 Evaluation, Memorandum to Forest Supervisor, San Bernardino NF, August 30, 1982). Subsequently, FPM measured conifer mortality that occurred on the Forest during the period May 1981 to May 1982. This report documents the findings of this latest survey.

Mortality estimates resulting from the 1976-1978 evaluation were believed to be average or below average. This was based on comparison with estimates of mortality from other parts of the Region. Near or above normal precipitation during the survey period was considered to be a major factor contributing to this low mortality. Precipitation during the 1980 water year[1/] was below normal in southern California. This provided the opportunity to examine mortality that occurs during drought conditions.

The objectives of the evaluation were:

1) To measure the level of tree mortality between May 1981 and May 1982 on the San Bernardino National Forest.

2) To determine the pests associated with the mortality.

3) To compare the level, characteristics, and causes of mortality following a year of below normal precipitation with that of previous years with normal to above precipitation.

The primary utility of this information is that it allows us to compare the results of these two evaluations. By noting differences between them, and considering important conditions that might be responsible for those differences, we can determine what may be useful in guiding future management practices.

Survey procedures were the same as those used during the 1976-78 evaluation. A few of the plots that had previously been used were deleted because of ongoing timber and fuelwood cutting activities. The general survey methodology has been developed during the past decade by the Region 5 FPM Staff and is referred to as the Pest Damage Inventory (PDI). The methodology is described in the Forest Insect and Disease Survey Methods Manual, Section 3.3.1, USDA Forest Service.

[1/] A water year is the period from July 1 to June 30. For example, the 1980 water year began on July 1, 1980 and ended on June 30, 1981.

RESULTS

Precipitation records from the National Oceanic and Atmospheric Administration were examined for Big Bear Lake, Idyllwild Fire Department, and Lake Arrowhead weather stations. All of these stations are within the confines of the San Bernardino National Forest. Figure 1 presents a summation of these records for the water years 1974 through 1981, as well as the 30-year averages. Precipitation during water year 1980, the year having the most immediate effect on the vegetation during the survey year, was 44 to 59% of normal at the three stations. Precipitation in water years 1974, 1975, and 1976, which would influence tree mortality during the 1976-78 survey years, averaged 68, 88, and 76% of normal, respectively, at the three stations.

The total estimated mortality during 1981-82 was almost 16,000 trees containing over 8 million board feet, or almost 1.5 million cubic feet (Tables 1 and 2). This includes only trees 12 inches dbh and larger. This converts to approximately 16,000 cords of wood. Five species were involved in the mortality, although two species, Jeffrey pine and white fir, comprised the majority of dead trees both in numbers (92%) and volume (94%). Coulter pine, a third significant species on the Forest, had considerably less mortality, especially in volume. The other two species, sugar pine and singleleaf pinyon pine, are of limited occurrence in the area surveyed and had small amounts of mortality. The average diameters measured at 4.5 feet above ground level (dbh) of the dead trees were: Jeffrey pine - 23.9 inches; white fir - 20.2 inches; Coulter pine - 18.4 inches; sugar pine - 30 inches; and singleleaf pinyon pine - 14 inches.

Three forest types are recognized on the Forest: ponderosa-Jeffrey pine, mixed conifer, and Coulter pine. The largest amount of mortality occurred in the ponderosa-Jeffrey pine type. This type occurs on the greatest number of acres on the Forest and, therefore, is expected to have the greatest mortality. The greatest number of dead trees per acre was in the mixed conifer type (Table 3). However, the dead volume per acre was greater in the ponderosa-Jeffrey pine type, a reflection of the much greater volume per tree of Jeffrey pine (Table 4).

The 1982 survey data were analyzed the same way as it had been for the 1976-78 survey. The analyses were done such that the results could be compared to determine the influences of changes in precipitation. Table 5 presents the overall mortality figures, in number of trees and volume, from the two surveys. Only mortality of Coulter pine declined in 1982. The change from the mean annual mortality in 1976-78 is sizeable overall and quite large for white fir.

During the 1982 survey, data were taken at each ground-checked mortality spot to determine the site index. Two classification systems were used, that of Meyer in the ponderosa-Jeffrey pine type and Dunning and Reineke in the mixed conifer type. No system exists for the Coulter pine type. Site indices were converted to comparable site classes and the number

and volume of dead trees in each site class for the two forest types were determined (Table 6). The estimated distribution of site classes on the commercial forest land base is: I - 1%; II - 4%; III - 26%; IV - 32%; and V - 37%.

Basal area data were collected at each ground-checked mortality spot. The mortality spots were separated into three basal area groups: <120 ft^2/ac; 120-200 ft^2/ac; and >200 ft^2/ac. This breakdown was selected based on local experience of satisfactory stocking levels for the three forest types: 120 ft^2/ac for Coulter pine, 120-200 ft^2/ac for Jeffrey pine, and 200 ft^2/ac for mixed conifer. These are general levels that will vary for specific site situations. The number of ground-checked dead trees and mortality spots in each group were determined and the average number of dead trees per mortality spot was calculated (Table 7).

Tables 8, 9, and 10 display the numbers and volumes of trees killed by each pest for the three main tree species. Forest type did not have a significant effect on the pests involved, therefore, the estimates were combined for each tree species in all forest types. Much of the mortality was a result of the actions of more than one pest, usually a pathogen and an insect (Figures 2-9). When mortality was attributed to more than one pest, it was partitioned equally among each of the pests involved to provide an estimate of the number of trees and volume of mortality by pest. Therefore, individual species of pests actually were present in a greater number and volume of dead trees than the estimates indicate. Nevertheless, estimates provide the relative level of pest activity as if each tree was killed by a single pest. Figures 2-9 are a more realistic presentation of the interactions of pests in tree mortality in this survey.

DISCUSSION

Tree mortality increased substantially during 1981-82 over the average annual mortality which occurred during 1976-78. An increase of 130% in the number of trees and 133% in volume was recorded. The largest increase was in white fir in number of trees, volume, and average tree volume. Jeffrey pine also had a larger number and volume of dead trees, although the average tree volume was about the same. A decrease in the number and volume of Coulter pines was measured, with an increase in average tree volume. This increase in mortality can be attributed primarily to the reduction in available moisture during 1980-81 as reflected in the amount of precipitation. Reduced available moisture increases tree stress and susceptibility to successful beetle attacks.

The three years prior to water year 1980 experienced considerably above normal precipitation each year. This increased moisture availability may have resulted in lower mortality during these three years. The effect would be to delay "normal" mortality until the trees were stressed. The below normal precipitation in 1980 could have been the stress that triggered the death of much of this "accumulated mortality".

The large increase in white fir mortality following a relatively short period of decreased precipitation is significant. A sizeable amount of the mortality occurred in the Jeffrey pine type where white fir should be a minor component (no more than 20% of the stand, in conjunction with species other than Jeffrey and ponderosa pine). This forest type is usually found on more xeric sites than the mixed conifer type where white fir is a larger component. We can speculate then that much of the white fir in the Jeffrey pine type was off-site and marginal even prior to the decreased soil moisture. This increase of white fir in the pine type is a result of the shade tolerance of white fir and its ability to reproduce and survive in the understory, and improved control of fire. Sporadic fires historically had limited the amount of white fir that exists in these stands. A second reason for increased white fir mortality is that it transpires at higher levels than ponderosa and Jeffrey pines even when moisture is limited. This would have the effect of more rapidly decreasing soil moisture and increasing tree stress. Another probable reason for increased white fir mortality is its higher "tolerance" of pests, permitting population increases during periods of reduced stress. True mistletoe (Phoradendron bolleanum ssp. pauciflorum), as a water parasite, is much less demanding than dwarf mistletoe of pines. Likewise, it appears that white fir can survive root infection by Fomes annosus better than can pines. Fir engravers (Scolytus ventralis) oftentimes attack trees causing patch killing of the cambium rather than tree mortality. This may indicate a weaker parasitic relationship than certain pine bark beetles whose successful attacks more often result in tree mortality. The ability of the flatheaded fir borer (Melanophila drummondi) to survive in living hosts causing little outward damage, although similar to the California flatheaded borer (Melanophila californica), allows this beetle to respond quickly to stress situations. However, although white fir may tolerate these pests and survive their effects during normal periods, when additional stress induced by drought occurs, the trees rapidly succumb, especially to the beetles.

The decrease in Coulter pine mortality between the two surveys can be explained partly by sampling. On one plot, trees that were identified by photointerpretation as dead had been removed prior to ground-checking. Also, one plot was not ground-checked because of time constraints. This lack of ground verification reduced the estimates of mortality. However, without this reduction the amount of Coulter pine mortality probably would have only approached the levels in 1977-78 and not exceeded them. Therefore, it appears that a short-term drought may not have much effect on Coulter pine, and only in the denser stands might mortality substantially increase.

The increase in Jeffrey pine mortality was largely attributed to California flatheaded borer (Melanophila californica) activity. The amount of Jeffrey pine beetle (Dendroctonus jeffreyi) - related mortality was about the same as that experienced during the mid-1970's. The reason the flathead-associated mortality showed such a marked increase may be that the Jeffrey pine that died were already infested at the onset of the 1980 drought. As these trees experienced moisture stress, the inplace flathead larvae, which can survive for several

years in living trees, were able to rapidly respond (grow and develop) to the suddenly favorable habitat and, ultimately, kill their hosts. By way of contrast, the Jeffrey pine beetle completes one generation per year, initiating its attacks from about mid-June through August in the San Bernardino/San Jacinto Mountains. Given that the attacking populations were sparse in the summer of 1981, at least two consecutive years of favorable (drought) conditions may have been required for the Jeffrey pine beetle to fully exploit the situation and cause substantial increases in tree mortality.

Overall, compared with the 1976-78 results, mortality caused by beetles alone increased as a proportion of the total. The suddenness and short-term nature of the drop in precipitation resulted in tree stress that was responded to more quickly and successfully by beetles. Disease agents do not have this ability to respond quickly to sudden stress - they usually cause stress rather than respond to it. It is important to note that although mortality caused by a combination of beetles and disease agents (pest complex) decreased from the previous survey, the pest complex still accounted for one-half or more of the mortality of each species.

Both the site class and basal area information indicate trends, but are inconclusive. The proportion of the mortality on the less productive sites is greater than the proportion of area occupied by these site classes. This supports the idea that initially, drought-induced mortality is more likely to occur on the poorer, harsher sites. Similarly, basal area appears to have some influence on the size of mortality groups. Although not as clearcut as that derived from the 1976-78 survey, higher stocking levels overall tend to have larger groups of dead trees.

CONCLUSION

A goal of the 1976 Southern California Timber Management Plan is to provide protection from excessive insect or disease losses by maintaining a healthy, vigorous forest. It is the resource manager's decision to determine if these mortality figures, in conjunction with field observations, represent excessive losses. The evaluation of the 1976-78 survey provided pest management prescriptions that, if implemented, could minimize tree losses. The results of this survey supports the appropriateness of these precriptions. Silvicultural treatments, especially thinning and sanitation, will be most effective in minimizing future losses. An active program of monitoring for pest-associated damage to resources can aid in determining if mortality levels are increasing and can provide stand-specific information for the use of the resource manager in deciding what actions are appropriate. Where resource values warrant protection efforts, an integrated pest management program of detection, prevention, and suppression will yield the best results.

TABLE 1. Number of Trees (dbh[1] ≥12) That Died Between May 1981 and May 1982 on the San Bernardino National Forest.

SPECIES	FOREST TYPE			TOTAL
	JEFFREY PINE	MIXED CONIFER	COULTER PINE	
Jeffrey pine	3273±914	1027±435	0	4300±1012
White fir	4968±1721	5296±692	50±50	10314±1856
Coulter pine	83±83	0	668±169	751±188
Sugar pine	248±248	0	0	248±248
Pinyon pine	124±124	171±171	0	295±211
TOTAL	8696±1745	6494±997	717±159	15907±2016

[1]dbh = diameter of bole in inches at 4.5 feet above ground.

TABLE 2. Volume (bf[1]) of Trees (dbh[2] ≥12) That Died Between May 1981 and May 1982 on the San Bernardino National Forest.

SPECIES	FOREST TYPE			
	JEFFREY PINE	MIXED CONIFER	COULTER PINE	TOTAL
Jeffrey pine	2898611+ 1035159−	540159+ 310457−	0	3438770+ 1080712−
White fir	1670614+ 625684−	2580096+ 1179596−	2480+ 2480−	4253190+ 1335265−
Coulter pine	57132+ 57132−	0	148311+ 78393−	205443+ 97003−
Sugar pine	243432+ 243432−	0	0	243432+ 243432−
Pinyon pine	4140+ 4140−	3424+ 3424−	0	7564+ 5372−
TOTAL	4873929+ 1288831−	3123680+ 1197194−	150791+ 78004−	8148400+ 1760808−

[1]bf = board feet Scribner.
[2]dbh = diameter of bole in inches at 4.5 feet above ground.

TABLE 3. Number and Volume (bf[1]) of Trees (dbh[2] ≥12) per Acre That Died Between May 1981 and May 1982 on the San Bernardino National Forest.

SPECIES	FOREST TYPE							
	JEFFREY PINE[3]		MIXED CONIFER[4]		COULTER PINE[5]		ALL TYPES[6]	
	No.	Vol.	No.	Vol.	No.	Vol.	No.	Vol.
Jeffrey pine	0.05	47.3	0.03	13.6	0	0	0.04	28.7
White fir	0.08	27.2	0.13	64.9	<0.01	0.1	0.09	35.4
Coulter pine	<0.01	0.9	0	0	0.04	7.9	0.01	1.7
Sugar pine	<0.01	4.0	0	0	0	0	<0.01	2.0
Pinyon pine	<0.01	0.1	<0.01	0.1	0	0	<0.01	0.1
TOTAL	0.14	79.5	0.16	78.6	0.04	8.0	0.13	68.0

[1] bf = board feet Scribner.
[2] dbh = diameter of bole in inches at 4.5 feet above ground.
[3] Area of type = 61,344 acres.
[4] Area of type = 39,760 acres.
[5] Area of type = 18,744 acres.
[6] Survey area = 119,848 acres.

TABLE 4. Average volume (bf[1]) per Tree of Trees (dbh[2] >12) That Died Between May 1981 and May 1982 on the San Bernardino National Forest.

SPECIES	FOREST TYPE			
	JEFFREY PINE	MIXED CONIFER	COULTER PINE	ALL TYPES
Jeffrey pine	886	526	0	800
White fir	336	487	50	412
Coulter pine	688	0	222	274
Sugar pine	982	0	0	982
Pinyon pine	33	20	0	26

[1]bf = board feet Scribner.
[2]dbh = diameter of bole in inches at 4.5 feet above ground

TABLE 5. Mean Annual Tree Mortality (dbh[1] ≥12) on the San Bernardino National Forest During the Survey Periods of 1976-78 and 1981-82.

SPECIES	NUMBER OF TREES 1976-78	NUMBER OF TREES 1981-82	VOLUME (MBF[2]) 1976-78	VOLUME (MBF[2]) 1981-82	VOLUME (BF[3])/ TREE 1976-78	VOLUME (BF[3])/ TREE 1981-82
White fir	2408	10314	544.5	4253.2	226	412
Jeffrey pine	3112	4300	2683.3	3438.8	862	800
Coulter pine	1390	751	273.7	205.4	197	274
TOTAL	6910	15907	3501.5	8148.4		

[1]dbh = diameter of bole in inches at 4.5 feet above ground.
[2]MBF = thousand board feet Scribner.
[3]BF = board feet Scribner.

TABLE 6. Number and Volume (mbf[1]) of Trees (dbh[2] ≥12) That Died on Each Site Class Between May 1981 and May 1982 on the San Bernardino National Forest.

SITE CLASS	FOREST TYPE				PERCENT OF TOTAL	
	JEFFREY PINE[3]		MIXED CONIFER[4]			
	Number	Volume	Number	Volume	Number	Volume
I	0	0	171	103	1	1
II	373	19	342	86	5	1
III	2,236	1,006	856	1,484	21	33
IV	1,739	2,021	2,540	1,074	29	40
V	4,018	1,504	2,414	368	44	24

[1]mbf = thousand board feet Scribner.
[2]dbh = diameter of bole in inches at 4.5 feet above ground.
[3]Classification system of W.H. Meyer. 1938. USDA Tech. Bull. 630.
[4]Classification system of D. Dunning and L.H. Reineke. 1933. USDA Tech. Bull. 354.

TABLE 7. Average Number of Dead trees per Mortality Group for Three Basal Area Classes for each of the Three Forest Types.

BASAL AREA (SQ.FT./AC)	FOREST TYPE: COULTER PINE		JEFFREY PINE		MIXED CONIFER		ALL TYPES	
< 120	1.4	(14/10)[1]	1.0	(11/11)	1.0	(14/14)	1.1	(39/35)
120 - 200	1.2	(12/10)	1.7	(12/7)	1.1	(22/20)	1.2	(46/37)
> 200	4.3	(13/3)	1.0	(2/2)	1.3	(20/15)	1.8	(35/20)
ALL CLASSES	1.7	(39/23)	1.3	(25/20)	1.1	(56/49)	1.3	(120/92)

[1]Fraction in parenthesis is the number of dead trees over the number of mortality groups ground-checked.

TABLE 8. Insects and Diseases Involved in White Fir Mortality Between May 1981 and May 1982 on the San Bernardino National Forest.

CAUSAL AGENT	NUMBER OF TREES	PERCENT OF TOTAL	VOLUME (MBF[1])	PERCENT OF TOTAL	VOLUME (BF[2])/ TREE
Fir Engraver	6620±1300	63	2359±753	56	356
Flatheaded Fir Borer	428±274	4	565±468	13	1320
Annosus Root Disease	1407±386	13	426±199	10	303
Armillaria Root Disease	533±229	5	599±461	14	1123
Fir True Mistletoe	1532±583	15	278±121	7	182
TOTAL	10520±1519	100	4227±1026	100	402

[1]mbf = thousand board feet Scribner.
[2]bf = board feet Scribner.

TABLE 9. Insects and Diseases Involved in Jeffrey Pine Mortality Between May 1981 and May 1982 on the San Bernardino National Forest.

CAUSAL AGENT	NUMBER OF TREES	PERCENT OF TOTAL	VOLUME(MBF[1])	PERCENT OF TOTAL	VOLUME (BF[2])/ TREE
Jeffrey Pine Beetle	1231±443	30	2000±887	57	1625
Red Turpentine Beetle	281±248	7	334±325	10	1189
California Flatheaded Borer	1159±541	28	529±431	15	457
Western Dwarf Mistletoe	354±148	9	325±186	9	918
Annosus Root Disease	791±408	19	199±125	6	251
Armillaria Root Disease	168±119	4	97±77	3	578
Pine Engraver	139±124	3	10±9	<1	69
TOTAL	4123±877	100	3494±1065	100	847

[1]mbf = thousand board feet Scribner.
[2]bf = board feet Scribner.

TABLE 10. Insects and Diseases Involved in Coulter Pine Mortality Between May 1981 and May 1982 on the San Bernardino National Forest.

CAUSAL AGENT	NUMBER OF TREES	PERCENT OF TOTAL	VOLUME(MBF[1])	PERCENT OF TOTAL	VOLUME (BF[2])/ TREE
Western Pine Beetle	368±160	50	141±78	69	382
Red Turpentine Beetle	127±46	17	24±19	12	190
California Flatheaded Borer	26±18	4	2±2	1	80
Western Dwarf Mistletoe	207±48	28	36±20	18	176
Armillaria Root Disease	16±16	2	2±2	1	127
TOTAL	744±175	100	205±83	100	276

[1]mbf = thousand board feet Scribner.
[2]bf = board feet Scribner.

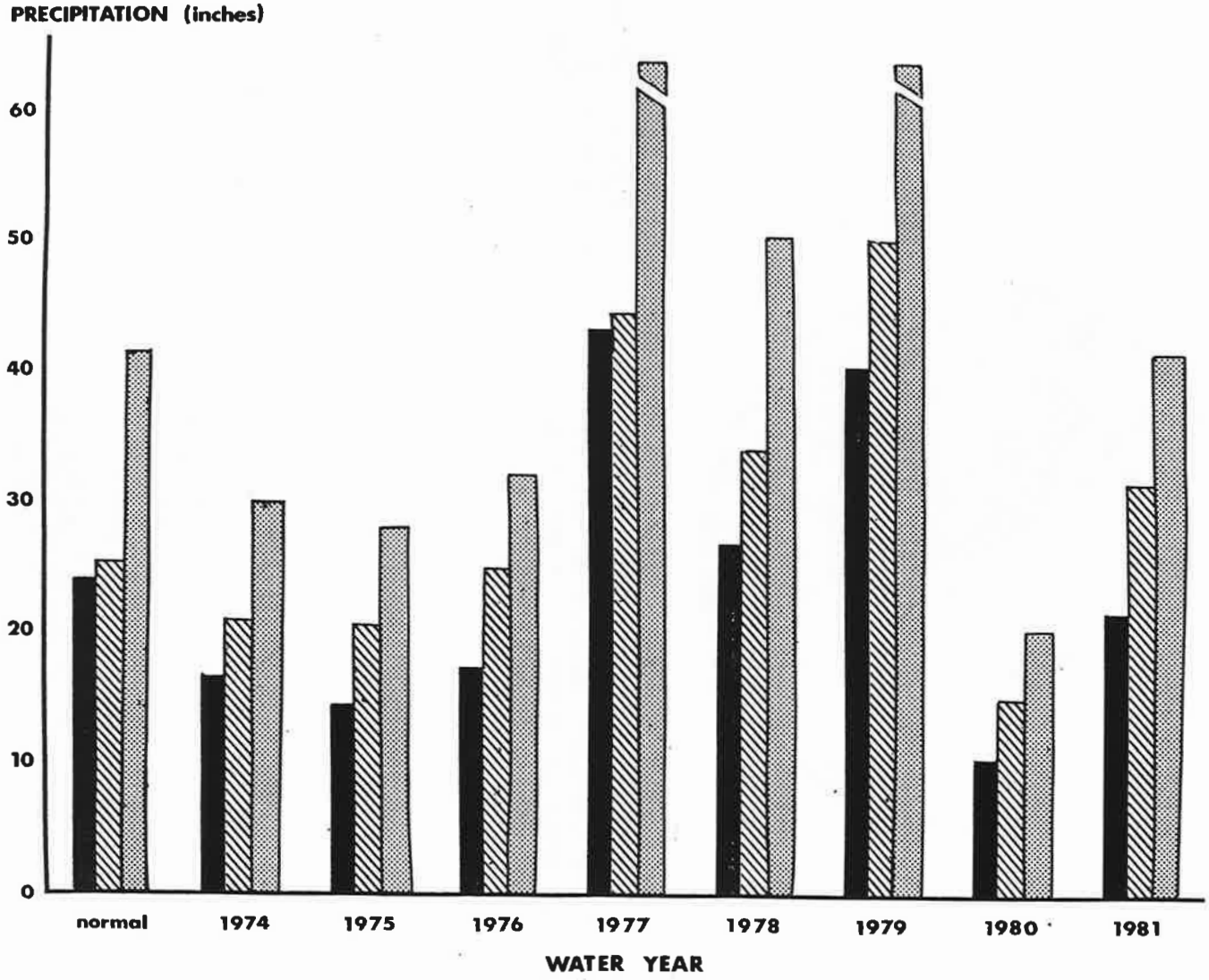

FIGURE 1. Precipitation (inches) during water years (July-June) at three locations on the San Bernardino National Forest (■ =Big Bear; ▨ =Idyllwild Fire Department; ▩ = Lake Arrowhead).

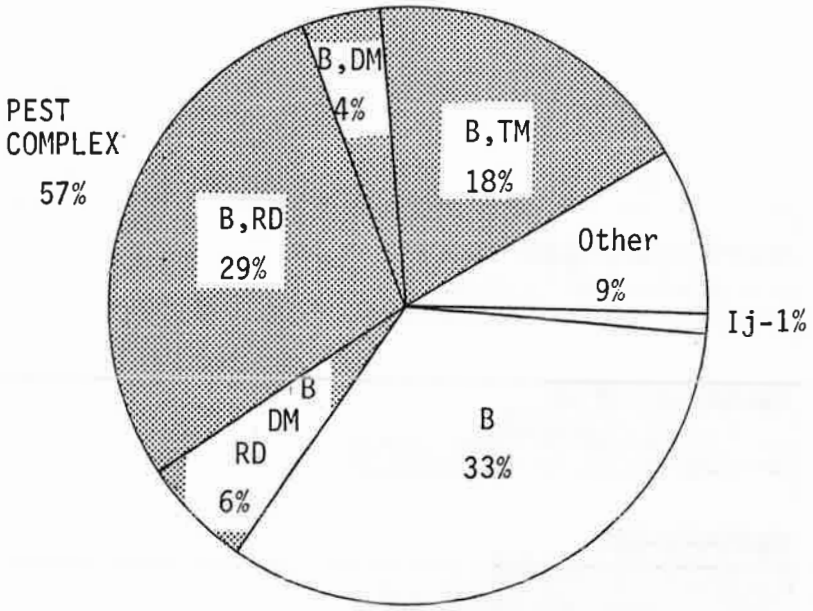

FIGURE 2. Percent distribution of the total number of trees that died between May 1981 and May 1982 on the San Bernardino National Forest (B=Beetles, DM=dwarf mistletoes, RD=root diseases, Ij=injury, TM=true mistletoe).

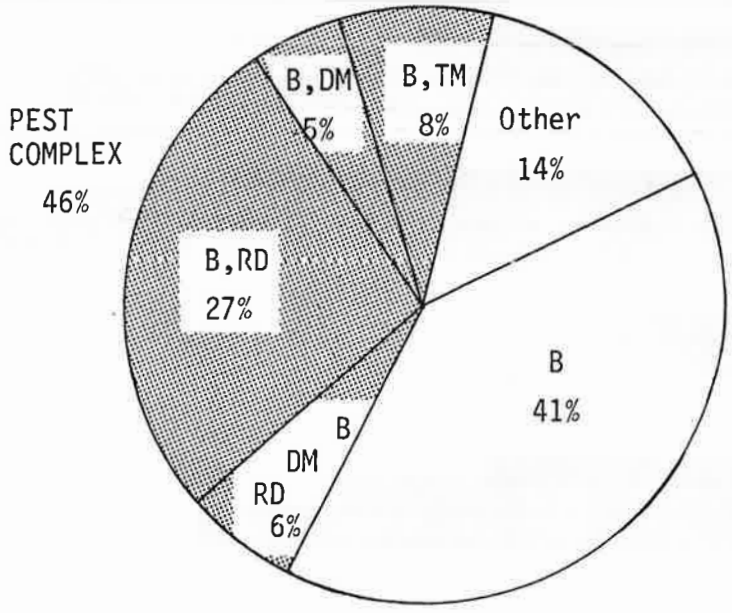

FIGURE 3. Percent distribution of the total volume of trees that died between May 1981 and May 1982 on the San Bernardino National Forest (B=Beetles, DM=dwarf mistletoes, RD=root diseases, TM=true mistletoe).

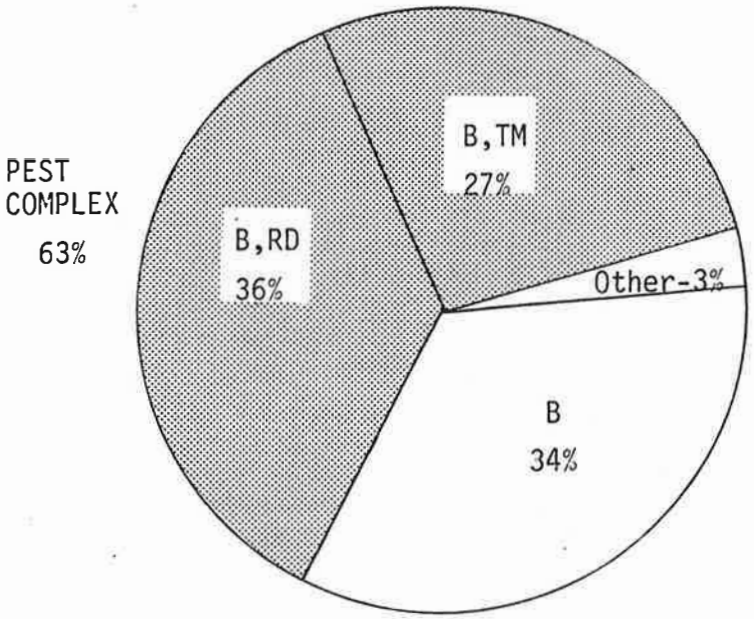

FIGURE 4. Percent distribution of the number of white firs that died between May 1981 and May 1982 on the San Bernardino National Forest (B=Beetles, RD=root diseases, TM=true mistletoe).

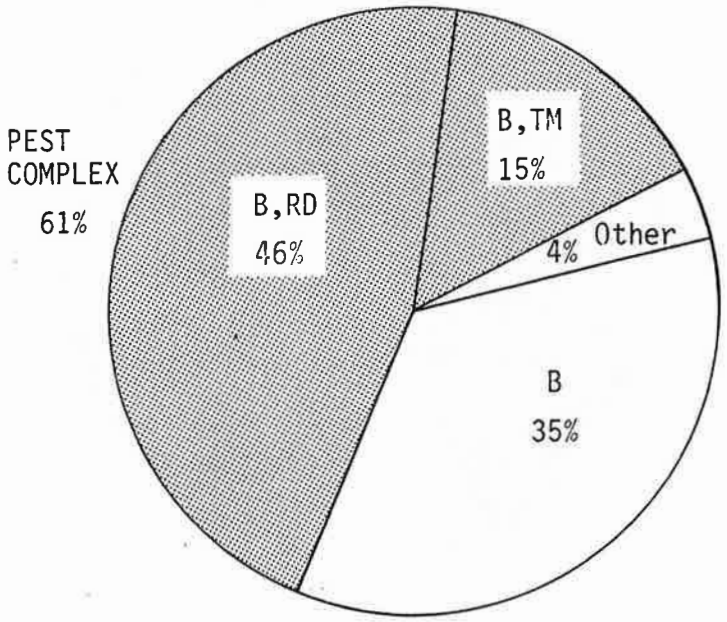

FIGURE 5. Percent distribution of the volume of white firs that died between May 1981 and May 1982 on the San Bernardino National Forest (B=Beetles, RD=root diseases, TM=true mistletoe).

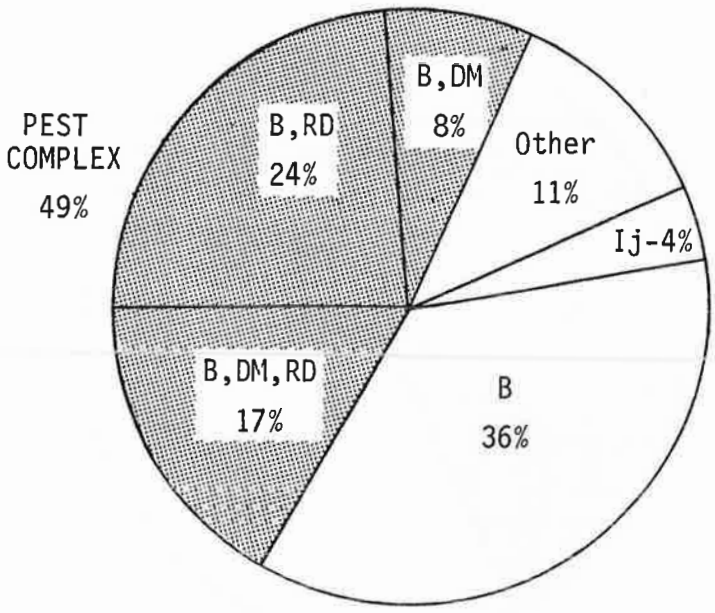

FIGURE 6. Percent distribution of the number of Jeffrey pines that died between May 1981 and May 1982 on the San Bernardino National Forest (B=Beetles, Ij=injury, DM=dwarf mistltoes, RD=root diseases).

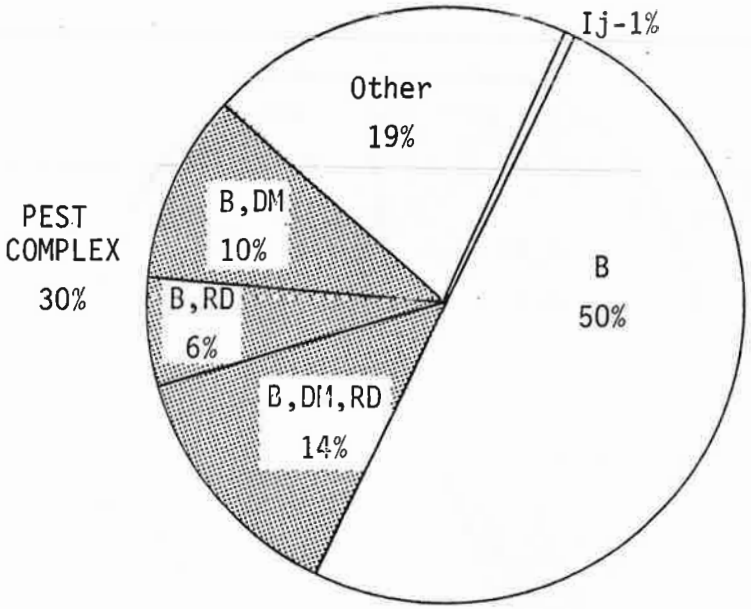

FIGURE 7. Percent distribution of the volume of Jeffrey pine that died between May 1981 and May 1982 on the San Bernardino National Forest (B=Beetle, Ij=injury, DM=dwarf mistletoes, RD=root diseases).

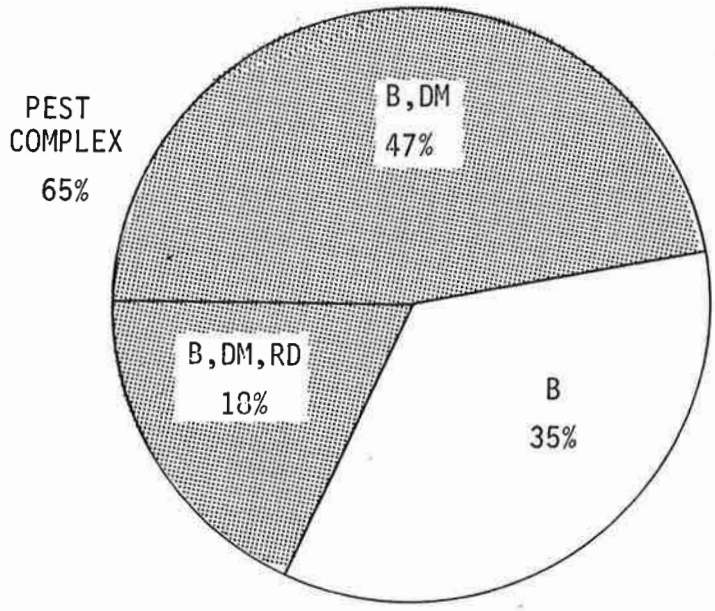

FIGURE 8. Percent distribution of the number of Coulter pines that died between May 1981 and May 1982 on the San Bernardino National Forest (B=Beetles, DM=dwarf mistletoes, RD=root diseases).

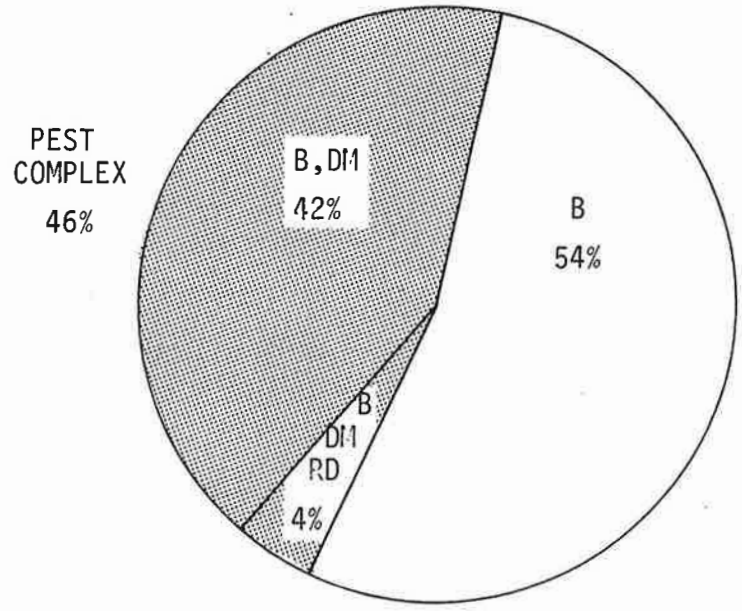

FIGURE 9. Percent distribution of the volume of Coulter pines that died between May 1981 and May 1982 on the San Bernardino National Forest (B=Beetles, DM=dwarf mistletoes, RD=root diseases).

ACKNOWLEDGEMENT

The authors acknowledge the assistance of Willard Hoskins in data compilation and statistical analysis.